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# Influence of rotational speed, torque and operator proficiency on failure of Greater Taper files

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## Abstract

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**Aim** The purpose of this study was to evaluate the influence of rotational speed, torque, and operator experience on the incidence of locking, deformation, and separation of instruments when using a specific Ni–Ti rotary instrumentation technique in extracted human teeth.

**Methodology** Greater Taper Ni–Ti rotary instruments (GT) were used in a crown-down technique. In one group (rotational speed evaluation) of canals ( $n = 300$ ) speeds of 150, 250 and 350 r.p.m. (subgroups 1, 2 and 3) were used. Each one of the subgroups included 100 canals. In a second group (evaluation of torque) ( $n = 300$ ) torque was set at 20, 30 and 55 Ncm (subgroups 4, 5 and 6). In the third group (evaluation of operator proficiency) ( $n = 300$ ) three operators with varying experience (subgroups 7, 8 and 9) were also compared. Each subgroup included the use of 10 sets of GT rotary instruments and 100 canals of extracted human molars. Each set of instruments was used in up to 10 canals and sterilized before each case. NaOCl 2.5% was used as an irrigant. The number of locked, deformed, and separated instruments was recorded for each group. Statistical analysis

was carried out with pairwise comparisons using Fisher's exact tests for each of the failure type.

**Results** When the influence of rotational speed was evaluated, instrument deformation and separation did not occur in subgroups 1 (150 r.p.m.), 2 (250 r.p.m.), and 3 (350 r.p.m.). Instrument locking occurred in subgroup 3 only. Statistical analysis demonstrated a significant difference between the 150 and 350 r.p.m. groups and between the 250 and 350 r.p.m. groups with respect to instrument locking. In torque evaluation, neither separation, deformation nor locking occurred during the use of the instruments, at 150 r.p.m., and at the different torque values. When the operators were compared, although two instruments were separated in canals prepared by the least experienced operator, Fisher's exact tests did not demonstrate a significant difference between the three subgroups. Instrument locking, deformation, and separation did not occur with the most experienced operator. None of the instruments separated with the trained operator.

**Conclusions** Preclinical training in the use of the GT rotary instruments when used with a crown-down technique at 150 r.p.m. was crucial in avoiding instrument separation and reducing the incidence of instrument locking and deformation.

**Keywords:** failure, Greater Taper files, nickel–titanium, operator's proficiency, rotational speed, torque.

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## Introduction

Instrument separation and deformation are serious concerns in root canal treatment. During shaping,

instruments might lock and/or thread (screw) into the canal. Locked instruments are subjected to high levels of stress, frequently leading to separation. Several studies have evaluated the influence of various factors on the fatigue life and resulting separation of endodontic Ni–Ti alloy instruments. In one study, the authors investigated the effect of rotational speed, angle of curvature, and radius of curvature on cyclic fatigue of Lightspeed rotary Ni–Ti instruments (Pruett *et al.* 1997). Ramirez-Solomon *et al.*

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(1997) evaluated the incidence of the Lightspeed separation. Thompson & Dummer (1997a,b) and Bryant *et al.* (1998) demonstrated that the incidence of Ni-Ti rotary instrument deformation and separation was related to instrument design and instrumentation technique.

The influence of operator experience was assessed in three studies that demonstrated proper tuition or experience was necessary to minimize the incidence of instrument separation (Barbakow & Lutz 1997, Mandel *et al.* 1999, Yared *et al.* 2001).

Pruett *et al.* (1997) found that the rotational speed did not affect cyclic fatigue of Lightspeed instruments. Gabel *et al.* (1999) and Yared *et al.* (2001) demonstrated that failure of ProFile Ni-Ti rotary instrument was less probable at a lower rotational speed.

Torque is another parameter that might influence the incidence of instrument locking, deformation, and separation. Theoretically, an instrument used with a high torque is very active and the incidence of instrument locking and, consequently, deformation and separation would tend to increase. Whereas a low torque would reduce the cutting efficiency of the instrument, and instrument progression in the canal would be difficult, the operator would then tend to force the instrument and may encourage instrument locking, deformation, and separation. Recently, Yared *et al.* (2001) evaluated the influence of torque on the incidence of ProFile failures. According to Kobayashi *et al.* (1997) torque should be set between 0.39 and 0.78 Ncm for ProFiles to avoid instrument failures. Svec & Powers (1999) compared the torque at failure values of used and unused ProFiles. They demonstrated that torque values at failure were very low for both used and unused instruments.

The Greater Taper (GT) Ni-Ti rotary instruments (Dentsply/Maillefer, Maillefer, Switzerland) are manufactured in 0.06, 0.08, 0.10, and 0.12 taper. All the instruments have the same tip diameter of 0.20 mm and a maximum flute diameter of 1.0 mm. The influence of various parameters on the failure of GT rotary instruments has never been tested.

The purpose of this study was to evaluate the influence of rotational speed, torque, and operator experience on the incidence of locking, deformation, and separation of GT Ni-Ti rotary instruments during repeated simulated clinical use, exposure to 2.5% NaOCl and steam autoclave sterilization.

## Materials and methods

The present study included three parts that assessed, respectively, the influence of rotational speed, torque, and

operator experience on the incidence of instrument locking, deformation, and separation. The same design was used in a recent study that evaluated ProFile instruments (Yared *et al.* 2001). Extracted human mandibular and maxillary first and second molars with mature apices and demonstrating curvatures  $>25^\circ$  (Schneider 1972) were used; the teeth were kept in 10% formalin at 37°C. Access cavities were prepared, the canal orifices located and the cavities irrigated with 2.5% NaOCl. Patency of the canals was determined with a size 06 K-type file (Dentsply/Maillefer, Ballaigues, Switzerland). Only canals having a snug fit with a .08 or 10 K-type file were included. The snugness indicated that the canal was narrow and suitable for inclusion in the study. The working length of each canal was determined by passing a size 06 file to the apical foramen and then subtracting 0.5 mm. Working length and reference points were recorded for each canal. Initial radiographs were taken from the buccal and proximal directions; exposure time and processing were standardized. The radiographs were used to detect canals that joined each other; in these cases only one canal was included in the study. The angle of curvature and the radius of curvature were determined on the initial buccal radiograph using the method of Pruett *et al.* (1997). Canals were ordered according to radius of curvature (least to greatest) then randomly and blindly assigned into three groups, such that all ranges of radii of curvature were equally represented in each group, and such that each group included 100 canals. In the three groups, GT instruments were used in a crown-down technique sequentially in a descending order of taper. The instruments were used in a handpiece in conjunction with a variable high torque motor (TC 3000 Maillefer) and used according to the following principles: the apical pressure exerted on the GT was light and each instrument was used for only a few s in the canal; the GT was used with small in and out movements. The canals were enlarged until a 0.08 taper GT reached the working length. Three to four recapitulations (waves) with GT taper 0.12–0.06 were required to complete cleaning and shaping of each canal. Preparation was judged to be complete when a 1–1 Machtou plugger (ISO size 50) penetrated to 5–7 mm short of the working length, and a fine-medium gutta-percha cone fitted 0.5 mm short of the working length. During shaping each canal was irrigated with 5 mL of 2.5% NaOCl using a 5/8-inch 27-gauge needle placed as far into the canal as possible without binding. The patency of the apical foramen was frequently checked by passing the tip of a size 08 file through the foramen. Before each use, the GT set (kit) was sterilized by steam autoclave for 5 min at 135°C; the whole cycle of sterilization lasted

35 min; the same set was used in up to 10 canals. Ten sets of four GT taper 0.12–0.06 were included in each of the three groups. A  $\times 2.5$  magnification was used to check for instrument deformation after each passage. An operator blinded to the study performed the instrument inspection. Instrument deformation, separation and locking within each group were recorded. The number of canals shaped by each instrument was also recorded. In case of instrument deformation or separation, the instrument was replaced. The number of instruments required to complete the cleaning and shaping of the 100 canals in each subgroup was recorded. In case of instrument locking, the rotation direction was reversed to disengage the instrument and shaping was completed after examining the instrument for deformation. The locked instruments were reused in the following canals and not discarded. Statistical analysis was carried out with pairwise comparisons using Fisher's exact tests for each of the failure types. The SAS 6.12 program for Windows (SAS, Cary, NC, USA) was used; significance was set at the 95% level.

In the first part of the study, the rotational speed was fixed at 150, 250, and 350 r.p.m. for subgroups 1, 2 and 3, respectively. The torque generated by the motor was set at 20 Ncm. The same operator performed the cleaning and shaping procedures in all the canals of the three groups. The canals of subgroup 1 were first prepared, followed by subgroup 2, and then by subgroup 3. In the second part of the study, the rotational speed for the three groups was fixed at 150 r.p.m. and the same operator performed the preparation procedures. The torque generated by the motor was set at 20, 30, and 55 Ncm for subgroups 4, 5, and 6, respectively. The canals were prepared in that order. In the third part of the study, the rotational speed was set at 150 r.p.m. for the three subgroups (7, 8 and 9) and the torque generated by the motor was fixed at 20 Ncm. Different operators performed the endodontic procedures in the three subgroups. In subgroup 7, an endodontist experienced in the instrumentation technique performed the cleaning and shaping. In subgroup 8, the operator

was trained on 30 clear resin endodontic blocks with curved canals and on 10 curved canals in extracted human molars. In subgroup 9, the operator was introduced to the technique without any training. The operators in subgroups 8 and 9 were general dentists whose degree of experience with respect to endodontics was limited to the training received in their undergraduate studies and to the experience acquired during 3 years of general practice.

## Results

### Rotational speed

The mean and standard deviation of the angle and radius of curvature within the three subgroups are listed in Table 1. The mean angle of curvature and the mean radius of curvature were 44.5° and 4.9 mm for subgroup 1, 45.2° and 4.7 mm for subgroup 2 and 43.9° and 5.1 mm for subgroup 3.

Instrument deformation and separation did not occur in any of the three subgroups. Instruments locked only in subgroup 3 (350 r.p.m.) with a significant difference between subgroups 1 and 3, and 2 and 3 (Table 2).

### Torque

The mean and standard deviation of the angle and radius of curvature within subgroups 4, 5 and 6 are listed in Table 1. The mean angle of curvature and the mean radius of curvature were 54.7° and 6.6 mm for subgroup 4, 54.2° and 7.1 mm for subgroup 5 and 54.9° and 6.9 mm for subgroup 6. Instrument locking, deformation, and separation did not occur in any of the three subgroups.

### Operator proficiency

The mean and standard deviation of the curvature angle and the curvature radius of subgroups 7, 8 and 9 are listed in Table 1.

**Table 1** Mean and standard deviation of the angle and radius of curvature of the three subgroups in the three parts of the study

| Part of the study                    | Subgroup        |                 |                 |
|--------------------------------------|-----------------|-----------------|-----------------|
| <i>Part 1 (Speed)</i>                | Subgroup 1      | Subgroup 2      | Subgroup 3      |
| Angle of curvature (degrees)         | 44.5 $\pm$ 1.58 | 45.2 $\pm$ 2.01 | 43.9 $\pm$ 1.13 |
| Radius of curvature (mm)             | 4.9 $\pm$ 0.21  | 4.7 $\pm$ 0.44  | 5.1 $\pm$ 0.24  |
| <i>Part 2 (Torque)</i>               | Subgroup 4      | Subgroup 5      | Subgroup 6      |
| Angle of curvature                   | 54.7 $\pm$ 1.72 | 54.2 $\pm$ 1.01 | 54.9 $\pm$ 1.23 |
| Radius of curvature                  | 6.6 $\pm$ 0.17  | 7.1 $\pm$ 0.32  | 6.9 $\pm$ 0.63  |
| <i>Part 3 (Operator proficiency)</i> | Subgroup 7      | Subgroup 8      | Subgroup 9      |
| Angle of curvature                   | 56.4 $\pm$ 0.17 | 54.9 $\pm$ 0.34 | 53.7 $\pm$ 0.11 |
| Radius of curvature                  | 4.9 $\pm$ 0.12  | 5.4 $\pm$ 0.11  | 5.4 $\pm$ 0.35  |

|             | Subgroup 1<br>(150 r.p.m.) | Subgroup 2<br>(250 r.p.m.) | Subgroup 3<br>(350 r.p.m.) |
|-------------|----------------------------|----------------------------|----------------------------|
| Locking     | 0/40*                      | 0/40                       | 23/40                      |
| Deformation | 0/40                       | 0/40                       | 0/40                       |
| Separation  | 0/40                       | 0/40                       | 0/40                       |

Subgroups joined with lines are significantly different ( $\alpha = 0.05$ ; d.f. = 1;  $P = 0.000003$ ).

\*Each group included a total of 40 instruments (10 sets of four instruments).

|             | Subgroup 7<br>(Experienced endodontist) | Subgroup 8<br>(Trained operator) | Subgroup 9<br>(Untrained operator) |
|-------------|-----------------------------------------|----------------------------------|------------------------------------|
| Locking     | 0/40* $P = 0.002$                       | 3/43 $P = 0.079$                 | 11/51                              |
| Deformation | 0/40 $P = 0.004$                        | 3/43                             | 9/51                               |
| Separation  | 0/40                                    | 0/43                             | 2/51                               |

Subgroups joined with lines are significantly different ( $\alpha = 0.05$ ; d.f. = 1).

\*Number of instruments required to complete the cleaning and shaping of the 100 canals included in each subgroup.

**Table 2** Rotational speed: incidence of instrument locking, deformation, and separation

**Table 3** Operator proficiency: incidence of instrument locking, deformation, and separation

The mean incidence of instrument locking, deformation, and separation is reported in Table 3. In subgroup 7, neither locking, deformation or separation occurred. In subgroup 8, only a small number of instruments locked and deformed; separation did not occur in this subgroup. Forty-three instruments were required to complete the cleaning and shaping of the 100 canals included in this subgroup. In subgroup 9, 11 out of 60, nine out of 60, and two out of 60 instruments were locked, deformed, and separated, respectively. Fifty-one instruments were required to complete the cleaning and shaping of the 100 canals included in this subgroup. Statistical analysis did not demonstrate any significant difference between groups 7 and 8 with respect to instrument locking, deformation, and separation. Instruments in subgroup 9 locked significantly more than the instruments in subgroups 7 and 8. The incidence of instrument deformation was statistically different between subgroups 7 and 9. There was no significant difference in the incidence of instrument separation between the three subgroups (Table 3).

A trend toward a higher incidence of instrument failure in smaller tapers was noted when the operators were evaluated. Nine out of 12 separated instruments and two out of two deformed instruments were 0.06 taper GT rotary instruments.

## Discussion

This is the first comprehensive study that has evaluated the influence of rotational speed, torque, and operator experience on the incidence of locking, deformation and separation of GT Ni-Ti rotary instruments during repeated simulated clinical use, after exposure to 2.5% NaOCl and with autoclave sterilization.

In the present study, apical enlargement was kept as small as practical according to the principles of Schilder (1974) and because in the opinion of the authors any greater apical enlargement should have been completed with hand instruments.

As in a recent study (Yared *et al.* 2001) it was impossible to standardize the number of recapitulations (waves). Canal width and anatomy influenced the frequency of recapitulations needed before a 0.08 taper instrument reached the working length. However, 3–4 recapitulations were sufficient for all the canals.

The instruments were inspected for deformation with  $\times 2.5$  magnification after each passage in the canal. In a previous study, we noted that deformations went undetected if magnification was not used (Yared *et al.* 1999). The use of a dental operating microscope, where available, might decrease the incidence of false negatives (undetected deformations).

## Rotational speed

The torque value set on the motor in this part of the study was empirically chosen on the basis, although not confirmed by Yared *et al.* (2001), that high torque values would not be safe. The motor used in this study allowed torque to vary between 10 and 55 Ncm; these are extremely high levels. In laboratory experiments, Kobayashi *et al.* (1997) indicated that the torque threshold for the auto torque-reverse mechanism in the Tri Auto ZX (Morita, Japan) for ProFile rotary instruments taper 4% should be set between 0.39 and 0.79 Ncm. Svec & Powers (1999) showed that torque at failure was 0.78, 1.06, and 1.47 Ncm for unused 0.04 taper Profile rotary Ni-Ti instruments sizes 25, 30 and 35, respectively.

Instrument locking, deformation, and separation did not occur in any of the canals shaped with GT instruments rotated at 150 and 250 r.p.m. Some instruments used at 350 r.p.m. locked. Rotational speed in the present study did not influence the incidence of GT failures. The results of the present study did not agree with those of Gabel *et al.* (1999) and Yared *et al.* (2001); however, different instruments were tested in those studies. The difference between the results of the present study and those of Yared *et al.* (2001) could be attributed to the taper of the instruments. GT instruments used in crown-down would be subjected to lower stress levels at their tip than the 0.06 taper Profile instruments (Blum *et al.* 1999). Consequently, the incidence of deformation and separation would decrease. Moreover, Thompson & Dummer (1997a, b) demonstrated that the design of the instrument and the specific instrumentation sequence adapted have influence on instrument failure. Kobayashi *et al.* (1997) did not find any difference between 240 and 280 r.p.m.; but these rotational speeds are too close and the instruments tested were ProFiles. Pruett *et al.* (1997) found that cyclic fatigue of Lightspeed Ni-Ti rotary instruments was not affected by the rotational speed. However, Lightspeed instruments have a completely different design and behave in a different way.

### Torque

Instrument locking, deformation, and separation did not occur with any of the three subgroups.

Based on the results of previous studies (Yared *et al.* 1999, 2000, 2001), the first part of the present study and the work by Gabel *et al.* (1999) lower speeds were deemed safer than a higher speed with respect to instrument failures. As a result, a speed of 150 r.p.m. was chosen in this part of the study.

As mentioned earlier, the motor used in this study allowed a torque range between 10 and 55 Ncm. Clearly, the significance of this part of the study would have been enhanced if more torque values were evaluated.

When the torque value set on the motor is greater than the maximum torque at failure of the instrument, separation may occur if the instrument is locked. Svec & Powers (1999) demonstrated that torque at failure values for ProFiles are relatively low. According to Kobayashi *et al.* (1997) the torque values for the ProFiles should be set between 0.39 and 0.79 Ncm. Although the torque values in this study were great, neither deformation nor separation occurred with the GT rotary instruments. This was probably due to the technique, the strict adherence of the operator to the clinical guidelines, and to the

minimal load exerted on the instruments. Yared *et al.* (2001) had also reported similar findings with Profile instruments. Kobayashi *et al.* (1997) demonstrated that increased load on the instrument resulted in torque increase. Sattapan *et al.* (2000) demonstrated that when Ni-Ti rotary instruments were used with a slight pumping motion, apical load exerted during instrumentation was relatively low and that torque at failure was significantly higher than torque during instrumentation. In the present study the instruments were used with a slight apical pumping as in the study of Sattapan *et al.* (2000). This fact would account for the excellent results obtained in the present study. Also, the results of Sattapan *et al.* (2000) would confirm that the technique of instrumentation influences the incidence of instrument failures (Thompson & Dummer 1997a,b).

Recently, motors that set torque values at minimal levels (less than 1 Ncm) have been introduced. These motors allow the torque value to be set at a level lower than the maximum torque at failure. In view of the results obtained in this part of the study (no deformation and separation with very high torque), these motors may not be useful for experienced operators. On the other hand, their use would be beneficial with less experienced operators and with students, especially if the torque is set at a level lower than the yield point. These motors would also be useful in canals having small radii of curvature.

### Operator proficiency

Instrument separation did not occur with the experienced endodontist, nor with the trained operator, confirming the results of previous studies (Yared *et al.* 1999, 2000, 2001) and of parts 1 and 2 of the present study performed under the same conditions. This fact demonstrates the reliability of the instrumentation technique when the technical guidelines are respected as well as the importance of preclinical training and experience. The incidence of locked, deformed and separated instruments with the untrained operator confirmed the significance of training. Although no statistically significant difference was detected amongst the three operators with regard to instrument separation, the results showed a trend toward separation with the untrained operator. This operator probably exerted excess apical pressure on the GT instruments (Kobayashi *et al.* 1997) and/or used them for too long in the canal. Consequently, the instruments locked into the canal and were subjected to a high level of torque, with the result that instrument separation occurred on two occasions. Other clinical factors, such as a severe canal curvature, narrow canal diameter (Sattapan *et al.* 2000),

and tilting of the handpiece so that the file becomes diverted from the long axis of the canal would also lead to increased load on the instrument, resulting in separation (Kobayashi *et al.* 1997). The results of part 3 confirm those of Barbakow & Lutz (1997), Yared *et al.* (1999, 2000, 2001) and Mandel *et al.* (1999) that training is necessary to avoid complications.

Interestingly, in a similar study using ProFiles (Yared *et al.* 2001), the incidence of failures with an untrained operator was significantly higher than with the untrained operator in the present study. This difference was probably related to the degree of experience in endodontics of the untrained operators in the two studies.

In the three parts of the present study, an experienced operator cleaned and shaped 700 curved canals with the GT instruments (subgroups 1–7). Instrument deformation and separation did not occur but instrument locking occurred at 350 r.p.m. This finding confirms the reliability of the technique and the results of a recent similar study using ProFiles at 150 r.p.m. (Yared *et al.* 2001). Thompson & Dummer (1997a) showed that approximately one ProFile deformed per canal, a phenomenon that was thought to be due to the tendency of the instrument within the canal to bind, with the result that the continuous rotation of the handpiece wound up the cutting blades. In their study, simulated canals in resin blocks were used; they also used Profile rotary instruments with a 4% taper. Instrumenting canals in resin blocks is also more difficult than in human teeth. Blum *et al.* (1999) demonstrated that ProFiles taper 4% are mostly active at their tip and so are subjected to a high level of stress. In another study, Thompson & Dummer (1997a,b) demonstrated clearly that the design of the instrument and the specific instrumentation sequence adopted would have an influence on instrument failure.

## Conclusions

The results of the present study suggest that instrument failures can be avoided when rotary GT instruments are used by a trained operator under simulated clinical conditions at 150 r.p.m. in a crown-down technique. The use of these instruments by an experienced operator at higher speeds (250 and 350 r.p.m.) under simulated clinical conditions also appeared safe.

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